THE *NUCLEAR NEWS* INTERVIEW

Motta: On light-water reactor materials

A new textbook published by the American Nuclear Society describes the fundamentals of the behavior of nuclear materials in light-water reactors.

Light Water Reactor Materials, Volume I: Fundamentals was recently published by the American Nuclear Society. Volume I, which covers both the materials science and nuclear engineering topics needed to understand the behavior of materials inside a nuclear reactor, will be accompanied by a second volume that focuses on applications. The book's authors are Arthur Motta, a professor of nuclear engineering at Pennsylvania State University, and Donald Olander, professor emeritus at the University of California at Berkeley.

Motta, a native of Brazil, says that his journey to a career in the nuclear industry started after high school in 1975 when he looked to major in physics in college. He was prompted by his parents, however, to study engineering as a better path to job opportunities. Motta entered the mechanical engineering program at the Federal University of Rio de Janeiro, but he still felt the tug of science. The engineering program offered a specialization in nuclear engineering, and so he pursued it because it connected him back to physics. Motta received a bachelor's degree in mechanical engineering in 1980 and a master's degree in nuclear engineering in 1983. He then came to the United States to study at the University of California at Berkeley, where he worked under the guidance of Professor Olander and received a doctorate in nuclear engineering in 1988.

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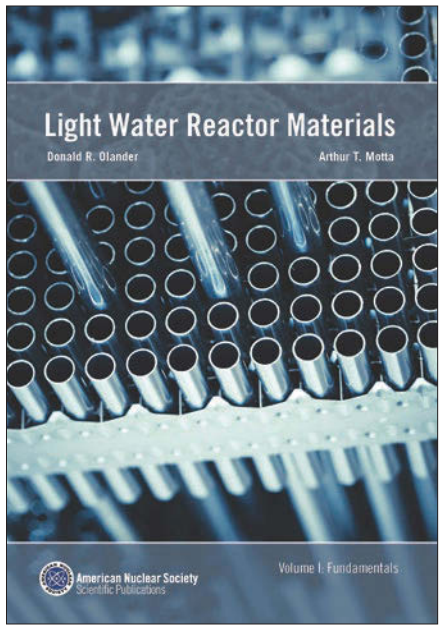
After receiving his Ph.D., Motta worked for two years as a research associate at the French Atomic Energy Commission's Center for Nuclear Studies in Grenoble, and for a year as a postdoctoral fellow at Atomic Energy of Canada Limited's Chalk River Laboratories. He joined the Penn State faculty in 1992 and went on to become chair of the university's Nuclear Engineering Program in the Department of Mechanical and Nuclear Engineering.

Motta is a Fellow of the American Nuclear Society, and in 2015 he received ANS's Mishima Award for outstanding contributions to research and development work on nuclear fuel and materials. In 2016, he was awarded ASTM International's William J. Kroll Zirconium Medal for contributions to the field of zirconium metallurgy in the areas of oxidation hydriding, deformation, and radiation damage. His research interests center on the behavior of nuclear materials in the reactor environment, especially using state-of-the-art characterization techniques that include transmission electron microscopy and synchrotron radiation diffraction and fluorescence to discern materials degradation mechanisms in service. He has over 120 publications to his credit, including several reviews and book chapters.

Rick Michal, director of ANS's Department of Scientific Publications and Standards, conducted this interview with Motta.

Light Water Reactor Materials, Volume I: Fundamentals is available through ANS and at Amazon.com.



Why did you and Don Olander decide to write this book?

Don published a seminal book on nuclear engineering in 1976 titled *Fundamental Aspects of Nuclear Reactor Fuel Elements*. It was used in nuclear engineering classes around the world and was the go-to book for learning about nuclear materials. Some people think that the new book that Don and I have coauthored is an update of Don's 1976 book, but it's really a completely new text.

I had the idea that I wanted to write a book about light-water reactor materials. Don was my doctoral advisor at Berkeley, and during a visit to the Berkeley campus I suggested that we write a book together. He was all for it, and we started working on it right away, but it went very slowly because of everything else that was going on in our lives. We knew it would take a great effort to capture everything that would need to go into the book. As anyone who teaches nuclear engineering knows, it's a very rewarding career, but it takes up a lot of your time and focus. We decided to divide the material into two volumes, one on fundamentals and the second on applications, and to publish Volume I on its own because the 15 chapters in Volume II were still in development.

How does the content of Volume I differ from what will be in Volume II?

Volume I focuses on the fundamental principles of thermodynamics, crystallography, diffusion, elasticity, dislocations, grain boundaries, nuclear heat production, phase transformations, mechanical behavior, radiation damage and microstructure evolution, and aqueous corrosion. There is also a chapter on computational materials written by Brian Wirth, a professor in the Nuclear Engineering Department at the University of Tennessee. We felt that having a chapter on computational materials by one of the leading experts in that area—which Brian is—was going to be very useful to students and to people coming into the field.

Volume II will cover applications of these principles, discussing specific materials-degradation phenomena, such as mechanical property changes, irradiation-induced deformation, corrosion, and hydriding, severe-accident analysis, and other phenomena that affect in-reactor materials performance.

Why is this book needed in the nuclear industry?

The purpose was to set down in a clear form our thoughts and our knowledge of the behavior of nuclear materials under irradiation in the nuclear reactor. The study of nuclear materials brings together knowledge from many different disciplines, such as chemistry, thermodynamics, materials science, and thermal hydraulics. All of these phenomena together are what affect the behavior of materials in the reactor, as reactor exposure changes material properties. We felt there was not yet a textbook that addressed all of these topics, which is why we decided to write it.

Who is the audience for the book?

The intended audience is graduate students in nuclear engineering, and perhaps senior undergraduates. Researchers in national laboratories who might be going into this area and want to get a refresher on the basics also can use it. Our approach was to try to make the book more physics-based than empirics-based, using analytical models that describe the phenomena so that readers can derive physical understanding of the processes that are taking place in materials inside the reactor.

Are you concerned that the book might quickly become outdated?

No, I'm not concerned, because we tried to base the writing on fundamental principles. A good example is Don's book from 1976, which, although focused on fast reactors, was written in such a fundamental way—starting from statistical thermodynamics—that it has remained relevant since then. Our new book is about the principles behind the applications. Because of that, we hope it will remain relevant for a long time. The principles of physics do not change.

While the existing fleet in the United States is made up of light-water reactors, future generations might not be. In view of that, do you believe the book will remain topical?

Ninety-five percent of all the reactors in the world are light-water reactors. If a utility were to build a reactor now, that is what it would build. The reactors with advanced designs—and I'm all in favor of developing them—for now are what Admiral Rickover would call "paper reactors." Great, but they're not here yet. There is a lot of development work that still needs to be done in order for a molten salt reactor, for example, to become operational. So, for the foreseeable future, this is what we have—light-water reactors.

How has it been working with Don Olander on this first volume?

Don is a great guy to work with. In your career as a researcher and as a professor, you'll find people who are good

to work with—people who are smart and knowledgeable, and who you can learn from. You try to maximize your chances of being with those people. Working with Don toward my doctorate was great, and I wanted to find more ways to work with him. This project was a way to do that and to continue to learn from him.

I want to mention that Don is an ANS Mishima Award winner for his contributions in the field of nuclear materials, especially in the area of fuel behavior, high-temperature chemistry, and the behavior of gases in solids. He also is an ANS Fellow and a member of the National Academy of Engineering, among many other distinctions.

How do you see student interest in nuclear engineering today?

At Penn State, students show great interest in nuclear, and we have the highest number of undergraduates in the United States, last year having graduated a full 14 percent of all the undergrads in nuclear engineering in the country. Although the Fukushima Daiichi accident caused a decrease of interest in nuclear in other countries, that doesn't seem to have happened in this country as much. Although the industry faces strong headwinds, we hope that people will wake up to the fact that the plants are valuable assets that provide clean energy and contribute to a decrease in greenhouse gas emissions. If we shut these plants down, it will be because we are not valuing them properly.

From your experience, are students who graduate with undergraduate nuclear engineering degrees going for employment in the nuclear industry, or are they turning elsewhere?

In spite of the problems in the industry, there are still 100 nuclear power plants operating in the United States. There also is employment available at the Nuclear Regulatory Commission, the Naval Nuclear Laboratory, national labs, electric utilities, nuclear fuel vendors, consulting companies, and an assortment of other places. Many of the people who work in these places are like me—not too far from retirement, maybe 10 or 15 years away. So there is going to be a wave of retirements coming, and employees will need to be replaced. Even Westinghouse, which announced bankruptcy a few months ago, is still going strong. The company's core business is still good, and it is still hiring.

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When do you expect Volume II to be published?

Don and I are working hard at it. We have the initial version of it, and we have given our editor—Steve Zinkle, a nuclear engineering professor at the University of Tennessee—five chapters to review. We are very thankful for all the support we've gotten from the American Nuclear Society, especially its Book Publishing Committee, which reviews and approves books for publication, and the ANS staff who work hands-on to get a book published. We're also very grateful to those nuclear engineering experts who have reviewed chapters and to the nuclear community for helping us out. Right now, our target for Volume II to be published is 2018. It is a goal that can be attained. **NN**